ORIGINAL ARTICLE

Color Doppler Echocardiographic Assessment of Valvular Regurgitation in Normal Infants

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Background/Purpose: Despite valvular regurgitation being a common finding in children, its prevalence in infants is unclear. The aim of this study was to determine the presence and severity of valvular regurgitation in normal infants using echocardiographic screening.

Methods: Two-dimensional (2D) color Doppler echocardiography was performed on 420 consecutive infants (aged 1–12 months) with structurally normal hearts. Pulsed, continuous-wave, and color Doppler imaging techniques were used to detect and evaluate regurgitant blood flow at each valve.

Results: Valvular regurgitation was present in 258 infants (61.4%). Among these, 41 (15.9%) were found to have a heart murmur. Tricuspid regurgitation was found in 237 (56.4%) infants, pulmonary regurgitation in 71 (16.9%), mitral regurgitation in 51 (12.1%), and aortic regurgitation in nine (2.1%). Regurgitation of one valve occurred in 161 (38.3%) infants, of two valves in 84 (20%), and of three valves in 13 (3.1%). Right-sided regurgitation was significantly more common than left-sided regurgitation ($p < 0.05$). The degree of regurgitation was trivial or mild in 97.3% of infants and the peak velocities of the regurgitant jets were ≤ 2.5 m/sec in all the valves, by Doppler echocardiography.

Conclusion: The prevalence of inaudible valvular regurgitation is high in infants with structurally normal hearts. Multiple-valve involvement with regurgitation is not uncommon. Mild severity and low velocity on color Doppler, and the structural information provided by 2D imaging strongly suggest that these regurgitant flows are physiologically normal in infancy. [*J Formos Med Assoc* 2010;109(1):56–61]

Key Words: Aortic value insufficiency, color Doppler echocardiography, mitral valve insufficiency, pulmonary valve insufficiency, tricuspid valve insufficiency

Valvular regurgitation is defined as the presence of turbulent flow that originates from a valve plane during the period of valve closure, which extends from the valve to its proximal chamber.[1] Doppler echocardiography is a noninvasive technique with a high degree of sensitivity and specificity in the diagnosis of valvular regurgitation.[1–7] The advent of echocardiography with color Doppler flow measurements provides a semiquantitative method for estimating the severity of regurgitation.[8–12] It is easy to obtain a dynamic display of the regurgitant flow patterns across the four cardiac valves and to localize the pulsed-wave and continuous-wave Doppler probes at the site of regurgitation.[12] Recent studies have found a very high frequency of valvular regurgitation in structurally normal hearts investigated by this color Doppler technique.[13–15] The reported prevalence of valvular regurgitation in normal subjects ranges from 0% to 100%.[8–17] Most previous

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studies of valvular regurgitation have been limited to adults,[1–10] Although some studies have enrolled limited numbers of pediatric patients, most of the studies were confined to children.[11,12,18–20] Whether the frequency and severity of valvular regurgitation in infants is the same as in older children is unclear. Therefore, this study was conducted prospectively to determine the presence and severity of valvular regurgitation in infants aged < 12 months, with structurally normal hearts, using two-dimensional (2D) color Doppler echocardiographic screening.

Materials and Methods

Subjects

This study was conducted at the outpatient department of Cathay General Hospital-Sijhih, Taipei, Taiwan between January 2006 and December 2007. Infants aged < 12 months who were brought to our department for health evaluation or referral for cardiac murmur were enrolled. After routine physical examination, the presence of a heart murmur was recorded. All infants were scanned thoroughly with 2D color Doppler echocardiography to detect valvular regurgitation as the primary cardiac lesion. Subjects who had abnormal anatomy of the atria, ventricles, and great arteries, and who had evidence of chamber enlargement, ventricular hypertrophy, wall motion abnormalities, ventricular dysfunction, valvular thickening, or prolapse were excluded.

Echocardiography

2D color Doppler echocardiography was performed using a commercial bedside ultrasound system (EnVisor C, Philips Ultrasounds, Andover, USA), with a 3.5- or 5-MHz transducer focused appropriately according to the size of the patient. Parasternal long- and short-axis views and apical four- and five-chamber views were obtained in all patients. For tricuspid regurgitation, the apical four-chamber view was utilized. Pulmonary regurgitation was examined in the parasternal short-axis view. The apical four-chamber and parasternal long-axis views were used to detect mitral regurgitation. The apical five-chamber and parasternal long-axis views were used for detection of aortic regurgitation. Color Doppler examinations were performed to detect the regurgitant flow across the four valves. The Doppler color gain was optimized by conventional methods. The mosaic colored jet was judged as regurgitation when it was observed as a reversed flow away from the valve.[11] Pulsed- and continuous-wave Doppler imaging examined flow patterns across the four cardiac valves to obtain a fully developed envelope on the Doppler spectral display.[18] The length of the regurgitant color flow jet from the tip of the measured valve was calculated. The severity of valvular regurgitation was graded according to Akasaka et al.[4]

Statistical analysis

Data are expressed as mean ± standard deviation. The χ^2 test was used to compare the frequencies of valvular regurgitation between the patients, who were stratified according to sex, and type and number of valves involved. A value of $p < 0.05$ was regarded as statistically significant.

Results

Prevalence and distribution

During the study period, 464 consecutive infants (242 male and 222 female) received complete echocardiographic scans. Forty-four infants were excluded because of other cardiac abnormalities found concomitantly: interatrial communications ($n = 28$), patent ductus arteriosus ($n = 6$), muscular ventricular septal defect ($n = 4$), and peripheral pulmonary stenosis ($n = 6$). A total of 420 subjects (226 male and 194 female) with a structurally normal heart were eligible for assessing valvular regurgitation.

According to the echocardiographic results, evidence of regurgitation of one or more valves was detected in 258 infants (61.4%), with 144 boys (55.8%) and 114 girls (44.2%). The prevalence of valvular regurgitation in male and female infants

was 63.7% and 58.8%, respectively. No association between sex and the presence of valvular regurgitation was found (Figure). Among the 420 infants who had structurally normal hearts by 2D echocardiography, 55 (13.1%) were found to have an audible murmur. Audible regurgitant murmurs were significantly less common than Doppler regurgitatant murmurs at all four valves. Among the infants with heart murmurs, 41 (74.5%) had valvular regurgitation. When analyzed by valve, infants with an audible murmur had a significantly higher prevalence of single valve regurgitation than those without murmurs ($p<0.05$; Table 1).

Doppler-detected regurgitation occurred most often at the tricuspid valves and was present in 237 (56.4%) infants. Pulmonary, mitral, and aortic regurgitation was found in 71 (16.9%), 51 (12.1%), and nine (2.1%) infants, respectively. Right-sided regurgitation was significantly more common than left-sided regurgitation ($p<0.05$). Regurgitation of just one valve was most frequently seen and occurred in 161 (38.3%) infants. This was followed by regurgitation of two valves in 84 (20.0%) infants, and regurgitation of

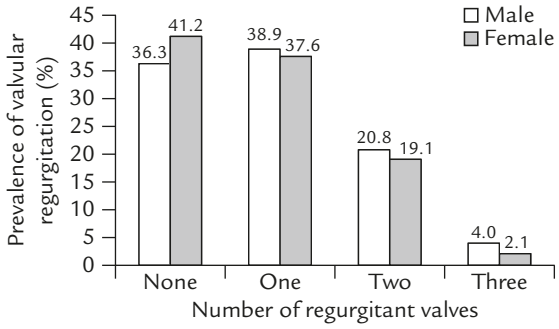

Figure. Prevalence of valvular regurgitation.

Table 1. Prevalence and distribution of color Doppler-detected valvular regurgitation in infants with normal two-dimensional echocardiograms*

Type of regurgitation	Infants with murmur ($n=55$)	Infants without murmur ($n=365$)
Single valve regurgitation	29 (52.7)	132 (36.5)†
TR	24	119
PR	4	8
MR	0	4
AR	1	1
Double valve regurgitation	6 (10.9)	78 (21.4)
TR and PR	4	42
TR and MR	1	31
TR and AR	1	2
MR and PR	0	1
MR and AR	0	1
AR and PR	0	1
Triple valve regurgitation	6 (10.9)	7 (1.9)
MR, TR and PR	5	6
MR, TR and AR	0	1
TR, PR and AR	1	0
Overall prevalence		
No regurgitation	14 (25.5)	148 (40.5)†
Any TR	36 (65.5)	201 (55.1)
Any PR	13 (23.6)	58 (15.9)
Any MR	7 (12.7)	44 (12.1)
Any AR	3 (5.5)	6 (1.6)

**Data presented as n or n (%); †p<0.05. TR=tricuspid regurgitation; PR=pulmonary regurgitation; MR=mitral regurgitation; AR=aortic regurgitation.*

three valves in 13 (3.1%) infants. No subject had regurgitation of more than three valves. In the 161 subjects with regurgitation of one valve, tricuspid regurgitation was the most common ($n=143$), followed by pulmonary regurgitation ($n=12$), mitral regurgitation ($n=4$), and aortic regurgitation ($n=2$). Within this subgroup with single-valve regurgitation, the order of prevalence of regurgitation according to valve position was identical to that found for the entire group (Table 1).

Semiquantification of valvular regurgitation

The degree and peak velocities of the regurgitant jets are shown in Table 2. Most (97.3%) of the regurgitant jets were confined to within 1.5 cm of the valve leaflets, which indicated that the regurgitant flows were just trivial or mild in severity. The prevalence of regurgitation of more than mild severity was much lower for all four valves (0–3.4%). The regurgitant velocities of the four valves were as follows: tricuspid regurgitation, 1.7–2.5 m/sec; pulmonary regurgitation, 0.9–1.4 m/sec; mitral regurgitation, 1.5–2.2 m/sec; and aortic regurgitation, 0.8–1.2 m/sec. The peak systolic velocity of tricuspid regurgitation was about 2.5 m/sec, which corresponded to a normal systolic pulmonary artery pressure. The peak diastolic velocity of pulmonary regurgitation corresponded to a normal right atrial pressure and pulmonary diastolic pressure. The peak velocities of mitral regurgitation were < 4 m/sec in all subjects, which represented the normal pressure difference between the left ventricle and left atrium during systole. Similarly, the peak velocities of aortic regurgitation were within the normal range.

Discussion

Despite Doppler-detected valvular regurgitation being common in children, its prevalence in small infants is still unclear.[18–20] Our data showed that valvular regurgitation was highly prevalent in infants with structurally normal hearts during the first year of life. The combination of all Doppler modalities (color-flow, pulsed-wave, and continuous-wave Doppler) used in the current study probably resulted in the relatively high prevalence. When valvular regurgitation was screened in non-selected populations using color Doppler echocardiography, many small regurgitant jets could be detected, which contributed to a higher prevalence in the present study (61.4%) compared with previously published results.[12,18–20] Another major finding in our study was that the prevalence of inaudible valvular regurgitation was high, which is consistent with previous results that the correlation of Doppler-detected regurgitation with audibility is somewhat poor.[4,7] The reason for this discrepancy in the reported prevalence of valvular regurgitation is the lack of uniform diagnostic criteria.[6] Yoshida et al[11] found that mitral regurgitation, tricuspid regurgitation, and pulmonary regurgitation were detected in 38–88% of apparently healthy persons by measuring regurgitation of > 100 millisecounds duration by M-mode color

Table 2. Severity of color Doppler-detected valvular regurgitation in infants with normal two-dimensional echocardiograms*

Regurgitant valve	Severity of regurgitation			Regurgitant flow	
	Trivial	Mild	Moderate	Velocity (m/sec)	Jet length (cm)
Tricuspid ($n=237$)	119 (50.2)	110 (46.4)	8 (3.4)	2.0 ± 0.3	0.6 ± 0.3
Pulmonary ($n=71$)	68 (95.8)	3 (4.2)	0 (0)	1.0 ± 0.2	0.3 ± 0.1
Mitral ($n=51$)	43 (84.3)	7 (13.7)	1 (2)	1.4 ± 0.3	0.3 ± 0.1
Aortic ($n=9$)	6 (66.7)	2 (22.2)	1 (11.1)	1.0 ± 0.2	0.4 ± 0.3

**Data presented as n (%) or mean ± standard deviation.*

flow mapping. Choong et al[1] reviewed 867 records from patients with structurally normal hearts, and have found that 34% had evidence of regurgitation of >200 milliseconds duration. Brand et al[12] defined regurgitation as having a duration of >100 milliseconds and a velocity of >1.2 m/sec. According to these criteria, 26.9% of 461 children were noted to have valvular regurgitation. Our definition of regurgitation based on the presence of typical mosaic jets that were visualized with color flow mapping, and a fully developed envelope that permitted regurgitant velocity measurement, as proposed by Van Dijk et al.[18] This method, which is useful for pressure estimation, is probably more precise than other methods.

Although there was a slightly higher prevalence of male infants with valvular regurgitation in our series, this difference was not significant. This result is consistent with previous investigations in which no sex difference was observed for valvular regurgitation.[6,9,13] Our study population was confined to subjects aged <12 months, therefore, an age-related effect on the presence of any type of regurgitation could not be demonstrated. Whether there is an increase in the prevalence of regurgitation with aging needs longitudinal follow-up.

A recent study using pulsed- and continuous-wave Doppler imaging in 174 normal children has shown rates of 32.8% tricuspid, 17.2% pulmonary, 8.6% mitral and 1.1% aortic regurgitation.[20] Our results are in accordance with this study with regard to the preponderance of Doppler-detected regurgitation in right-sided valves. One possible explanation is that, in children with a narrow chest, the transducer can be positioned closer to the right side of the heart, which thereby increases the likelihood of detection of regurgitation.[6,20] Second, the tricuspid valve is more vulnerable to regurgitation because the initial structural valve is more complicated than the mitral valve leaflet.[21] Sugiyama et al found that the tricuspid valve takes decades to mature functionally.[21] The low prevalence of mitral and aortic regurgitation in the present study seems to indicate better preservation of left-sided valvular integrity in infancy.[12]

The peak velocity of the regurgitant jet is related to the pressure difference between the two chambers.[6] Based on the modified Bernoulli equation, the normal pressure difference should result in a peak regurgitant velocity about 1 m/sec for the pulmonary value, 2 m/sec for the tricuspid valve, and 4 m/sec for the mitral and aortic valves.[22] The regurgitant velocities of the right-sided valves recorded in our study were similar to those expected velocities. However, peak regurgitant velocities of the left-sided valves were <4 m/sec in all our subjects. According to Berger's explanation, the highest regurgitant velocities might be underestimated because of a weak Doppler signal or inadequate alignment of the ultrasound beam.[6] Another possible reason is that the modified Bernoulli equation does not apply to the small regurgitant orifices present in normal subjects.[6] As shown by Holen et al,[23] when the orifice diameter is <1.5 mm, viscous friction can result in a peak velocity that is lower than expected. Therefore, these Doppler characteristics in relation to the structural information provided by 2D imaging strongly suggest that these regurgitant flows are physiologically normal.[10] Although such regurgitation generally is accepted as a common benign finding in normal subjects, it does appear to represent true transvalvular regurgitation, and not merely volume displacement caused by valve closure.[10,16] Whether Doppler-detected valvular regurgitation is clinically significant and needs further attention depends on the clinical circumstances.[3,7] Mild right-sided regurgitation in the setting of an anatomically normal valve with normal ventricular size and function is almost of minimal clinical importance.[7] In contrast, regurgitation associated with an audible murmur and definite functional abnormality of a valve is always clinically significant.[7] However, there is some agreement that the presence of left-sided regurgitation, especially of the aortic valve, should be suspected as a disease rather than a physiological finding.[1,12–14] A possible cause for the valvular incompetence should be sought carefully.[12]

In conclusion, there is a high prevalence of inaudible valvular regurgitation in infants with

structurally normal hearts during the first year of life. It might be attributable to the advent of echocardiography with color Doppler flow measurements, which has allowed even very small regurgitant jets to be discovered. Tricuspid regurgitation is the most frequently detected and aortic regurgitation the least detected. Multiple-valve involvement with mild regurgitation is not uncommon. Most of the regurgitant flows are characteristic of trivial or mild severity and low velocity by Doppler echocardiography, which suggests that these findings are physiologically normal. To avoid unnecessary anxiety, the parents should be informed of this benign physiological valvular regurgitation. Long-term follow-up is warranted to detect whether this mild regurgitant flow remains unchanged or increases with age.

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